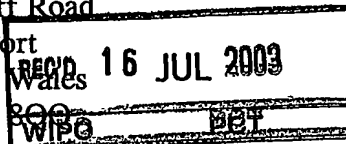




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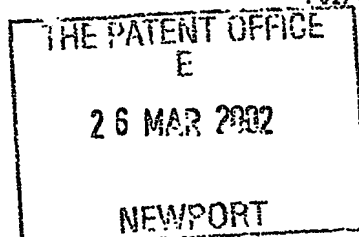
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1. Your reference	P451285		
2. Patent application number (The Patent Office will fill in this part)	0207176.9	26 MAR 2002	
3. Full name, address and postcode of the or of each applicant (underline all surnames)	Enfis Limited Technium Kings Road The Docks SWANSEA SA1 8PH Patents ADP number(if you know it) If the applicant is a corporate body, give the country/state of its incorporation England & Wales		
4. Title of the invention	Light Emitting Apparatus		
5. Name of your agent (if you have one)	Urquhart-Dykes & Lord	ABEL & IMRAY	
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	Alexandra House 1 Alexandra Road SWANSEA SA1 5ED United Kingdom	20 Red Lion Street LONDON WC1R 4PQ	
Patents ADP number(if you know it)	1644005 00000174001		
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know the or each application number	Country	Priority application number (if you know it)	Date of filing (day / month / year)
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing (day / month / year)	
8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))	Yes		

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

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Description	7
Claim(s)	6
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Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	0
Request for preliminary examination and search (Patents Form 9/77)	✓
Request for substantive examination (Patents Form 10/77)	0
Any other documents (please specify)	0

11. I/We request the grant of a patent on the basis of this application

Signature

Date 26 March 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Mr G M Davies

01792 474327

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Light Emitting Apparatus

5 The present invention relates to light emitting apparatus.

In order to maintain efficient light output from light emitting apparatus such as high brightness LED arrays or laser diode arrays and to increase the lifetime under
10 operating conditions it is beneficial for the light emitting device (or array of devices) to be provided with an effective heat removal system. An improved light emitting apparatus having a highly efficient cooling system has been devised.

15

According to the present invention, there is provided:

Light emitting apparatus comprising:

20 a) a light source arrangement; and

b) a cooling system comprising:

i) a heat conductive zone in heat transfer
25 relationship with the light source arrangement;

ii) a thermoelectric cooling device in heat transfer relationship with the heat conductive zone; and

30

iii) a heat pipe arrangement in heat transfer relationship with the thermoelectric cooling device.

5 It is preferred that the light source arrangement comprises a semi-conductor light source and/or a laser light source. The light source arrangement beneficially comprises a plurality of discrete light sources advantageously arranged in an array. The relevant devices may comprise LED (solid
10 state) devices and/or laser devices such as solid state laser devices.

The heat conductive zone beneficially comprises a layer of high thermal conductivity material arranged contiguously
15 with the light source arrangement. Beneficially the heat conductive zone is $50\mu\text{m}$ or less in thickness (more beneficially $20\mu\text{m}$ or less in thickness, most beneficially $10\mu\text{m}$ or less in thickness).

20 The heat conductive zone is beneficially a layer of deposited high thermal conductivity material, preferably deposited by plasma/chemical vapour deposition techniques. The high thermal conductivity material is advantageously deposited directly on a surface of the light source
25 arrangement (for example such as a rear heat transmissive surface of LED devices or a heat sink mounting for an array of such devices). Beneficially the high thermal conductivity zone comprises a layer of diamond material. Other suitable materials include zinc oxide and/or sapphire
30 material and/or silver material. Heat flowing from the

light source arrangement (typically the array of discrete light sources comprising the light source arrangement) is spread over a larger area by the high thermal conductivity spreader layer.

5

Beneficially the thermoelectric cooling device comprises a Peltier cooling device having a proximal end contiguous with the distal end of the heat conductive zone and a distal end contiguous with a proximal end of the heat pipe arrangement. The thermoelectric cooling device is beneficially arranged to be controlled to determine the heat transfer out of the heat conductive zone and/or into the heat pipe arrangement. The thermoelectric/Peltier device beneficially includes control means (typically appropriate drive circuitry) for controlling the current to the thermoelectric device for such purpose. Using the thermoelectric/Peltier device to control the heat transfer away from the heat conductive zone (and therefore away from the light source arrangement), thermal management of the light source arrangement can be optimised and accurately controlled.

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The heat pipe cooling arrangement beneficially includes a proximal portion contiguous with the thermoelectric cooling device and a distal portion provided with a condenser arrangement. The heat pipe cooling arrangement typically carries a coolant fluid to be heated by heat passing out of the thermoelectric cooling device. The coolant is beneficially directed (when heated) in a direction away from the thermoelectric device. The coolant is

25

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beneficially arranged to be directed away from the thermoelectric device by means of capillary action and/or diffusion. Heat pipe arrangements known in the art may be sufficient for use in accordance with the apparatus of the invention. The coolant is directed toward a cooling zone in the distal region of the heat pipe arrangement, the coolant being returned in the direction of the thermoelectric device following cooling at the cooling zone (for example by means of the condenser where present). Beneficially the coolant (for example or refrigerant) is arranged to vaporise under transfer of heat from the thermoelectric cooling device.

The heat pipe arrangement preferably includes a proximal zone contiguous with the thermoelectric cooling device and a distal cooling zone. The apparatus beneficially further includes force cooling means for cooling the heat pipe arrangement in the region of the distal cooling zone. The force cooling means may comprise water cooling means (for example a water jacket) and/or air cooling means such as an air fan or the like.

Beneficially, the apparatus includes an elongate housing having a proximal portion emitting light from the light source arrangement, and a distal portion proximate the distal portion of the heat pipe arrangement. The light source arrangement, heat conductive zone, thermoelectric cooling device and heat pipe arrangement, are beneficially arranged in the sequence specified and in-line with one another.

According to a second aspect, the present invention provides a light source arrangement cooling system, the cooling system comprising:

- 5 i) a heat conductive zone in heat transfer relationship with the light source arrangement;
- ii) a thermoelectric cooling device in heat transfer relationship with the heat conductive zone; and
- 10 iii) a heat pipe arrangement in heat transfer relationship with the thermoelectric cooling device.

15 The invention will now be further described, by way of example only, with reference to the accompanying drawing which is a schematic representation of apparatus in accordance with the invention.

20 Referring to the drawing, there is shown light emitting apparatus (generally designated 1) comprising, in sequence, an LED diode array 2, a high thermal conductivity heat spreader layer 3, a Peltier type thermoelectric cooler 4 and a heat pipe arrangement 5 (including a distal condenser

25 6) .

Heat flowing from the LED diode array 2 is spread over a larger area by the high conductivity spreader layer 3. This layer is typically only a few microns thick and

30 provides rapid and highly efficient heat transfer away from

the diode array 2. Heat then flows into the cold (?) end of the thermoelectric Peltier cooler 4. The hot (?) end of the thermoelectric Peltier cooler layer 4 is in heat transfer coupling with the heat pipe 5. The LED diode array may be arranged to emit light at any desired wavelength (or wavelength combination or wavelength band or wavelength band combination) and may be operated in pulsed or continuous wave mode. Typically the high thermal conductivity layer 3 includes a diamond material and may be plasma/chemical vapour deposition deposited. Other suitable materials include, for example, sapphire materials, zinc oxide materials, silver materials and the like.

The Peltier cooler 4 will typically include control means including associated drive circuitry to accurately control the heat transfer away from the LED diode array via the high thermal conductivity spreader layer 3. Accurate control of the driven Peltier thermoelectric cooler 4 (in combination with the provision of the high thermal conductivity heat spreader layer 3 and the downstream heat pipe cooling arrangement 5) provides for extremely efficient thermal management of the apparatus, and in particular, the diode array 2 to ensure consistency of output and maximum life of the diode array.

The heat pipe arrangement 5 may be of a variety generally known in the art and include a wick to direct fluid coolant (contained in the heat pipe arrangement 5) away from the "hot zone" via capillary action, gravity or diffusion. The

arrangement may include a fluid return system to return cooled fluid from the "cold zone" at the distal end of the apparatus (for example the distal region provided with condenser 6). The condenser 6 may be force cooled for
5 example by air cooling or water cooling.

The present invention provides significant advantages in terms of the synergistic combination of the high thermal conductivity spreader layer 3, the thermoelectric Peltier
10 cooler 4 and the cooling pipe arrangement 5 in enabling closely controlled and efficient thermal management of the LED diode array 2. Typically the arrangement is housed in an elongate housing having a proximal end via which light is emitted from the LED diode array. This arrangement in
15 which the high thermal conductivity heat spreader layer 3, the thermoelectric Peltier cooler device 4 and the heat pipe arrangement 5 are arranged, in sequence, and in-line with one another provides an apparatus/device which is convenient for hand-held manipulation and use particularly
20 when the overall length of the apparatus in the housing is 50cm or less.

CLAIMS:

1. Light emitting apparatus comprising:

5

a) a light source arrangement; and

b) a cooling system comprising:

10

i) a heat conductive zone in heat transfer relationship with the light source arrangement;

15

ii) a thermoelectric cooling device in heat transfer relationship with the heat conductive zone; and

20

iii) a heat pipe arrangement in heat transfer relationship with the thermoelectric cooling device.

2. Apparatus according to claim 1, wherein the light source arrangement comprises a semiconductor light source.

25

3. Apparatus according to claim 1 or claim 2, wherein the light source arrangement comprises a laser light source.

30

4. Apparatus according to any preceding claim, wherein

the light source arrangement comprises a plurality of discrete light sources (for example arranged in an array).

- 5 5. Apparatus according to any preceding claim, wherein
the light source arrangement comprises an LED array.
- 10 6. Apparatus according to any of claims 1 to 4, wherein
the light source arrangement comprises a laser diode
array.
- 15 7. Apparatus according to any preceding claim, wherein
the heat conductive zone comprises a layer of high
thermal conductivity material contiguous with the
light source arrangement.
8. Apparatus according to claim 7, wherein the heat
conductive zone is $50\mu\text{m}$ thick or less.
- 20 9. Apparatus according to claim 8, wherein the heat
conductive zone is $20\mu\text{m}$ thick or less.
10. Apparatus according to claim 9, wherein the heat
conductive zone is $10\mu\text{m}$ thick or less.
- 25 11. Apparatus according to any preceding claim, wherein
the heat conductive zone is a layer of deposited high
thermal conductivity material preferably
plasma/chemical vapour deposited.

30

12. Apparatus according to claim 11, wherein the deposited high thermal conductivity material is deposited on the surface of the light source arrangement.

5

13. Apparatus according to any preceding claim, wherein the high thermal conductivity zone comprises a diamond material and/or a zinc oxide material and/or a sapphire material, and/or a silver material.

10

14. Apparatus according to any preceding claim, wherein the thermoelectric cooling device comprises a Peltier cooling device.

- 15 15. Apparatus according to any preceding claim, wherein the thermoelectric cooling device is arranged to be controlled to determine the heat transfer out of the heat conductive zone and/or into the heat pipe arrangement.

20

16. Apparatus according to claim 15, wherein the apparatus includes control means for controlling the current to the thermoelectric device.

- 25 17. Apparatus according to any preceding claim, wherein the heat pipe cooling arrangement includes a proximal portion contiguous with the thermoelectric cooling device and a distal portion provided with a condenser device.

30

18. Apparatus according to any preceding claim, wherein
the heat pipe arrangement carries a coolant fluid to
be heated by the thermoelectric cooling device and be
directed (when heated) in a direction away from the
thermoelectric device.
5
19. Apparatus according to claim 18, wherein the coolant
is arranged to be directed away from the
thermoelectric device by means of capillary action
and/or diffusion.
10
20. Apparatus according to claim 18 or claim 19, wherein
the coolant is directed toward a cooling zone in the
distal region of the heat pipe arrangement, the
coolant being returned in the direction of the
thermoelectric device following cooling and the
cooling zone.
15
21. Apparatus according to any of claims 18 to 20, wherein
the coolant is arranged to vaporise under transfer of
heat from the thermoelectric cooling device.
20
22. Apparatus according to claim 21, wherein the coolant
is arranged to condense at a distal cooling zone of
the heat pipe arrangement.
25
23. Apparatus according to any preceding claim having an
elongate housing having a proximal portion emitting
light from the light source arrangement and a distal
portion proximate the distal portion of the heat pipe
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arrangement. The light source arrangement, heat conductive zone, thermoelectric cooling device, and heat pipe arrangement are arranged in sequence and in-line with one another.

5

24. Apparatus according to any preceding claim, wherein the heat pipe arrangement includes a proximal zone contiguous with the thermoelectric cooling device and a distal cooling zone, the apparatus further including force cooling means for cooling the heat pipe arrangement in the region of the distal cooling zone.

10

25. Apparatus according to claim 24, wherein the force cooling means comprises water cooling means.

15

26. Apparatus according to claim 24 or claim 25, wherein the force cooling means comprises air cooling means (such as an air fan or air compressor).

20

27. A cooling system for a light source arrangement, the cooling system comprising:

i) a heat conductive zone in heat transfer relationship with the light source arrangement;

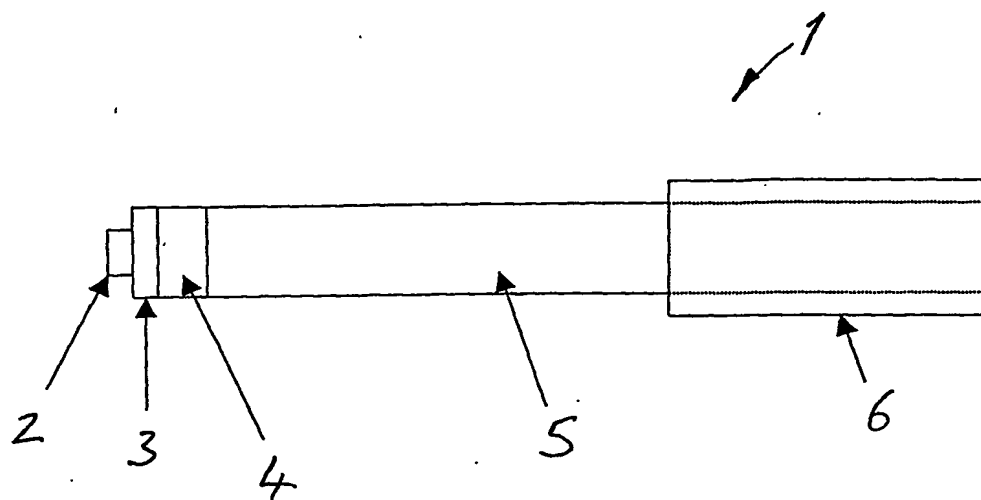
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ii) a thermoelectric cooling device in heat transfer relationship with the heat conductive zone; and

30

iii) a heat pipe arrangement in heat transfer relationship with the thermoelectric cooling device.

5 28. Apparatus substantially as herein described with reference to the accompanying drawings.



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